AN ANALYSIS OF THE AQUATIC INVERTEBRATES AND HABITAT OF TWO SITES ON BIG SPRING CREEK, FERGUS COUNTY: 2001 BIOASSESSMENT AND TRENDS SINCE 1990

A report to

The Montana Department of Environmental Quality
Helena, Montana

by

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October, 2001

INTRODUCTION

Aquatic invertebrates are aptly applied to bioassessment since they are known to be important indicators of stream ecosystem health (Hynes 1970). Long lives, complex life cycles and limited mobility mean that there is ample time for the benthic community to respond to cumulative effects of environmental perturbations

This report summarizes data collected in late May 2001 from two sites on Big Spring Creek, Fergus County, Montana. Aquatic invertebrate assemblages were sampled by personnel of the Montana Department of Environmental Quality (DEQ) at the Burleigh easement (above Lewistown) and at the Old County Farm (below Lewistown) sites. These same sites were also sampled in earlier years; data is available from sampling events in 1990, 1991, 1994, and 1996. In addition, a sample from the Burleigh easement site was taken in 1998. This report summarizes a bioassessment analysis of the two sites for 2001, for the Burleigh easement site in 1998, and provides a trend analysis for all years of sampling. Previous years' sampling included additional sites on Big Spring Creek but this report is limited to the sites at Burleigh easement and the Old County Farm. The object of this study is to compare the biotic integrity of Big Spring Creek above and below Lewistown, and to examine trends at the two sites over time.

Study sites lie within the Montana Valleys and Foothill Prairies ecoregion (Woods et al 1999) A multimetric approach to bioassessment such as the one applied in this study uses attributes of the assemblage in an integrated way to measure biotic health. A stream with good biotic health is "...a balanced, integrated, adaptive system having the full range of elements and processes that are expected in the region's natural environment ..." (Karr and Chu 1999). The approach designed by Plafkin et al. (1989) and adapted for use in the State of Montana has been defined as "... an array of measures or metrics that individually provide information on diverse biological attributes, and when integrated, provide an overall indication of biological condition." (Barbour et al. 1995). Community attributes that can contribute meaningfully to interpretation of benthic data include assemblage structure, sensitivity of community members to stress or pollution, and functional traits. Each metric component contributes an independent measure of the biotic integrity of a stream site, combining the components into a total score reduces variance and increases precision of the assessment (Fore et al. 1995). Effectiveness of the integrated metrics depends on the applicability of the underlying model, which rests on a foundation of three essential elements (Bollman 1998). The first of these is an appropriate stratification or classification of stream sites, typically, by ecoregion. Second, metrics must be selected based upon their ability to accurately express biological condition. Third, an adequate assessment of habitat conditions at each site to be studied is needed to assist in the interpretation of metric outcomes.

Implicit in the multimetric method and its associated habitat assessment is an assumption of correlative relationships between habitat parameters and the biotic metrics, in the absence of water quality impairment. These relationships may vary regionally, requiring an examination of habitat assessment elements and biotic metrics and a test of the presumed relationship between them. Bollman (1998) has recently studied the assemblages of the Montana Valleys and Foothill Prairies ecoregion, and has recommended a battery of metrics specific to that ecoregion, which has been shown to be sensitive to impairment, related to habitat assessment parameters and consistent over replicated samples.

Habitat assessment enhances the interpretation of biological data (Barbour and Stribling 1991), because there is generally a direct response of the biological community to habitat degradation in the absence of water quality impairment. If biotic health appears more damaged than the habitat quality would predict, water pollution by metals, other toxicants, high water temperatures, or high levels of organic and/or nutrient pollution might be suspected. On the other hand, an "artificial" elevation of biotic condition in the presence of habitat degradation may be due to the paradoxical effect of mild nutrient or organic enrichment in an oligotrophic setting.

METHODS

Aquatic invertebrates were sampled by Montana DEQ personnel on August 13, 1998 at the Burleigh easement site, and on May 25, 2001 at the Burleigh site and at the Old County Farm site on Big Spring Creek. Both sites had previously been sampled in 1990, 1991, 1994, and 1996. Sites are described, and sampling dates indicated in Table 1. The sampling method employed was that recommended in the Montana Department of Environmental Quality (DEQ) Standard Operating Procedures for Aquatic Macroinvertebrate Sampling (Bukantis 1998). In addition to aquatic invertebrate sample collection, habitat quality was visually evaluated at both sites and reported by means of the habitat assessment protocols recommended by Bukantis (1998). Habitat assessment was performed in most sampling years, however, only the 2001 habitat assessment results are reported in this study. In 2001, habitat assessment was performed by T.Pick of NRCS and by students of Lewistown Junior High School in Lewistown, Montana.

Table 1. Sampling sites: two sites on Big Spring Creek. 1990-2001

Site designation	Legal description	Location description
Burleigh	T15N, R18E, S36, NE¼, NE¼	Above Lewistown
Old County Farm	T15N, R18E, S4, SW¼, SW¼	Below Lewistown

Evaluated habitat features include instream conditions, larger-scale channel conditions including flow status, streambank condition, and extent of the riparian zone. Scores were assigned in the field to each habitat measure, and these scores were totaled and compared to the maximum possible score to give an overall assessment of habitat.

Aquatic invertebrate samples and associated habitat data were delivered to Rhithron Biological Associates, Missoula, Montana, for laboratory and data analyses. In the laboratory, the Montana DEQ-recommended sorting method was used to obtain subsamples of at least 300 organisms from each sample, when possible. Organisms were identified to the lowest possible taxonomic levels consistent with Montana DEQ protocols.

To assess aquatic invertebrate communities in this study, a multimetric index developed in previous work for streams of western Montana ecoregions (Bollman 1998) was used. Data from all previous years' sampling had been analyzed and interpreted

using an older index; all data from previous years were re-analyzed using the newer method Multimetric indices result in a single numeric score, which integrates the values of several individual indicators of biologic health. Each metric used in this index was tested for its response or sensitivity to varying degrees of human influence. Correlations have been demonstrated between the metrics and various symptoms of human-caused impairment as expressed in water quality parameters or instream, streambank and stream reach morphologic features. Metrics were screened to minimize variability over natural environmental gradients, such as site elevation or sampling season, which might confound interpretation of results (Bollman 1998). The multimetric index used in this report incorporates multiple attributes of the sampled assemblage into an integrated score that accurately describes the benthic community of each site in terms of its biologic integrity. In addition to the metrics comprising the index, other metrics, which have been shown to be applicable to biomonitoring in other regions (Kleindl 1995, Patterson 1996, Rossano 1995) were used for descriptive interpretation of results. These metrics include the number of "clinger" taxa, long-lived taxa richness, the percent of predatory organisms, and others. They are not included in the integrated bioassessment score, however, since their performance in western Montana ecoregions is unknown However, the relationship of these metrics to habitat conditions is intuitive and reasonable.

The six metrics comprising the bioassessment index used in this study were selected because both individually and as an integrated metric battery, they are robust at distinguishing impaired sites from relatively unimpaired sites (Bollman 1998). In addition, they are relevant to the kinds of impacts that are present in the Big Spring Creek drainage, including agricultural activities, recreation, and urbanization. The metrics have been demonstrated to be more variable with anthropogenic disturbance than with natural environmental gradients (Bollman 1998). Each of the six metrics developed and tested for western Montana ecoregions is described below.

1. **Ephemeroptera (mayfly) taxa richness.** The number of mayfly taxa declines as water quality diminishes. Impairments to water quality which have been demonstrated to adversely affect the ability of mayflies to flourish include elevated water temperatures, heavy metal contamination, increased turbidity, low or high pH, elevated specific conductance and toxic chemicals. Few mayfly species are able to tolerate certain disturbances to instream habitat, such as excessive sediment deposition.
2. **Plecoptera (stonefly) taxa richness.** Stoneflies are particularly susceptible to impairments that affect a stream on a reach-level scale, such as loss of riparian canopy, streambank instability, channelization, and alteration of morphological features such as pool frequency and function, riffle development and sinuosity. Just as all benthic organisms, they are also susceptible to smaller scale habitat loss, such as by sediment deposition, loss of interstitial spaces between substrate particles, or unstable substrate.
3. **Trichoptera (caddisfly) taxa richness.** Caddisfly taxa richness has been shown to decline when sediment deposition affects their habitat. In addition, the presence of certain case-building caddisflies can indicate good retention of woody debris and lack of scouring flow conditions.

4. **Number of sensitive taxa.** Sensitive taxa are generally the first to disappear as anthropogenic disturbances increase. The list of sensitive taxa used here includes organisms sensitive to a wide range of disturbances, including warmer water temperatures, organic or nutrient pollution, toxic pollution, sediment deposition, substrate instability and others. Unimpaired streams of western Montana typically support at least four sensitive taxa (Bollman 1998).

5. **Percent filter feeders.** Filter-feeding organisms are a diverse group; they capture small particles of organic matter, or organically enriched sediment material, from the water column by means of a variety of adaptations, such as silken nets or hairy appendages. In forested montane streams, filterers are expected to occur in insignificant numbers. Their abundance increases when canopy cover is lost and when water temperatures increase and the accompanying growth of filamentous algae occurs. Some filtering organisms, specifically the Arctopsychid caddisflies (*Arctopsyche* spp. and *Parapsyche* sp.) build silken nets with large mesh sizes that capture small organisms such as chironomids and early-instar mayflies. Here they are considered predators, and, in this study, their abundance does not contribute to the percent filter feeders metric.

6. **Percent tolerant taxa.** Tolerant taxa are ubiquitous in stream sites, but when disturbance increases, their abundance increases proportionately. The list of taxa used here includes organisms tolerant of a wide range of disturbances, including warmer water temperatures, organic or nutrient pollution, toxic pollution, sediment deposition, substrate instability and others.

Scoring criteria for each of the six metrics are presented in Table 2. Metrics differ in their possible value ranges as well as in the direction the values move as biological conditions change. For example, Ephemeroptera richness values may range from zero to ten taxa or higher. Larger values generally indicate favorable biotic conditions. On the other hand, the percent filterers metric may range from 0% to 100%; in this case, larger values are negative indicators of biotic health. To facilitate scoring, therefore, metric values were transformed into a single scale. The range of each metric has been divided into four parts and assigned a point score between zero and three. A score of three indicates a metric value similar to one characteristic of a non-impaired condition. A score of zero indicates strong deviation from non-impaired condition and suggests severe degradation of biotic health. Scores for each metric were summed to give an overall score, the total bioassessment score, for each site in each sampling event. These scores were expressed as the percent of the maximum possible score, which is 18 for this metric battery.

The total bioassessment score for each site was expressed in terms of use-support. Criteria for use-support designations were developed by Montana DEQ and are presented in Table 3a. Scores were also translated into impairment classifications according to criteria outlined in Table 3a.

In this report, certain other metrics were used as descriptors of the benthic community response to habitat or water quality but were not incorporated into the bioassessment metric battery, either because they have not yet been tested for reliability in streams of western Montana, or because results of such testing did not show them to be

Table 2. Metrics and scoring criteria for bioassessment of streams of western Montana ecoregions (Bollman 1998).

	score			
metric	**3**	**2**	**1**	**0**
Ephemeroptera taxa richness	> 5	5 - 4	3 - 2	< 2
Plecoptera taxa richness	> 3	3 - 2	1	0
Trichoptera taxa richness	> 4	4 - 3	2	< 2
Sensitive taxa richness	> 3	3 - 2	1	0
Percent filterers	0 – 5	5.01 - 10	10.01 - 25	> 25
Percent tolerant taxa	0 – 5	5.01 - 10	10.01 - 35	> 35

robust at distinguishing impairment, or because they did not meet other requirements for inclusion in the metric battery. These metrics and their use in predicting the causes of impairment or in describing its effects on the biotic community are described below.

- The modified biotic index. This metric is an adaptation of the Hilsenhoff Biotic Index (HBI, Hilsenhoff 1987), which was originally designed to indicate organic enrichment of waters. Values of this metric are lowest in least impacted conditions. Taxa tolerant to saprobic conditions are also generally tolerant of warm water, fine sediment and heavy filamentous algae growth (Bollman, unpublished data). Loss of canopy cover is often a contributor to higher biotic index values. The taxa values used in this report are modified to reflect habitat and water quality conditions in Montana (Bukantis 1998). Ordination studies of the benthic fauna of Montana's foothill prairie streams showed that there is a correlation between modified biotic index values and water temperature, substrate embeddedness, and fine sediment (Bollman 1998). In a study of reference streams, the average value of the modified biotic index in least-impaired streams of western Montana was 2.5 (Wisseman 1992).
- Taxa richness. This metric is a simple count of the number of unique taxa present in a sample. Average taxa richness in samples from reference streams in western Montana was 28 (Wisseman 1992). Taxa richness is an expression of biodiversity, and generally decreases with degraded habitat or diminished water quality. However, taxa richness may show a paradoxical increase when mild nutrient enrichment occurs in previously oligotrophic waters, so this metric must be interpreted with caution.
- Percent predators. Aquatic invertebrate predators depend on a reliable source of invertebrate prey, and their abundance provides a measure of the trophic complexity supported by a site. Less disturbed sites have more plentiful habitat niches to support diverse prey species, which in turn support abundant predator species.
- Number of "clinger" taxa. So-called "clinger" taxa have physical adaptations that allow them to cling to smooth substrates in rapidly flowing water. Aquatic invertebrate "clingers" are sensitive to fine sediments that fill interstices between substrate particles and eliminate habitat complexity. Animals that occupy the

hyporheic zones are included in this group of taxa. Expected "clinger" taxa richness in unimpaired streams of western Montana is at least 14 (Bollman, unpublished data).

- Number of long-lived taxa. Long-lived or semivoltine taxa require more than a year to completely develop, and their numbers decline when habitat and/or water quality conditions are unstable. They may completely disappear if channels are dewatered or if there are periodic water temperature elevations or other interruptions to their life cycles. Western Montana streams with stable habitat conditions are expected to support six or more long-lived taxa (Bollman, unpublished data).

Table 3a. Criteria for the assignment of use-support classifications / standards violation thresholds (Bukantis, 1997)

% Comparability to reference	Use support
>75	Full support--standards not violated
25-75	Partial support--moderate impairment--standards violated
<25	Non-support--severe impairment--standards violated

Table 3b. Criteria for the assignment of impairment classifications (Plafkin et al. 1989)

% Comparability to reference	Classification
> 83	nonimpaired
54-79	slightly impaired
21-50	moderately impaired
<17	severely impaired

RESULTS

Habitat assessment

Figure 1 compares habitat assessment results from 2001 for the two sites in this study. Table 4 itemizes the evaluated habitat parameters and shows the assigned scores for each. Optimal habitat conditions at the upper site, Burleigh, are suggested by the assessment. Mild deposition of fine sediments may compromise habitat to some degree, and embeddedness of substrate particles was judged slight. Streambanks were perceived to be stable and well-vegetated, but the riparian zone was limited in width. Field notes indicate that agricultural land use above the site was primarily hay and pasture, with range and forested cover present as well. Previous habitat assessments of the Burleigh site rated instream and riparian habitat optimal in three of four years. In 1994, habitat was judged sub-optimal.

At the Old County Farm site below Lewistown, overall habitat conditions were perceived to be sub-optimal. Considerable channel alteration was present, and moderate

sediment deposition was reported, with associated slight-to-moderate embeddedness of substrate particles. Some streambank instability was also noted. The riparian zone width on one bank was judged poor. Field notes indicate that land use in the vicinity of the site was agricultural (hay and pasture), but that urban development was present as well. Some disturbance at the site was associated with the bridge below the site. In all previous years, overall habitat conditions at the Old County Farm site were assessed as sub-optimal, though scores assigned in 1994 and 1996 suggested improvement. The total bioassessment score calculated for this site in 2001 suggests a diminishment of habitat quality to levels similar to 1990 and 1991. Comparisons of habitat assessments over the years is difficult, however, since different investigators assessed sites in each year, and habitat assessment measures changed several times over the period of study.

Bioassessment

Aquatic invertebrate taxa lists, metric results, and other information for each of the samples taken in 1998 and 2001 are given in the Appendix. Figure 2 summarizes bioassessment scores for aquatic invertebrate communities at the two sites in each year of the study. Table 5 itemizes each contributing metric and shows individual metric scores for both sites in all years for which data were available. Data from 1990, 1991, 1994, and 1996 were re-analyzed and scores calculated to be consistent with current methods in use in the western Montana ecoregions. Thus, assessments may differ from those made in reports written in previous years. Table 3 shows criteria for impairment classifications and use-support categories recommended by Montana DEQ.

Figure 2. Total bioassessment scores for two sites on Big Spring Creek in six years of sampling. Scores are expressed as percent of maximum possible score. Sites are described in Table 1.

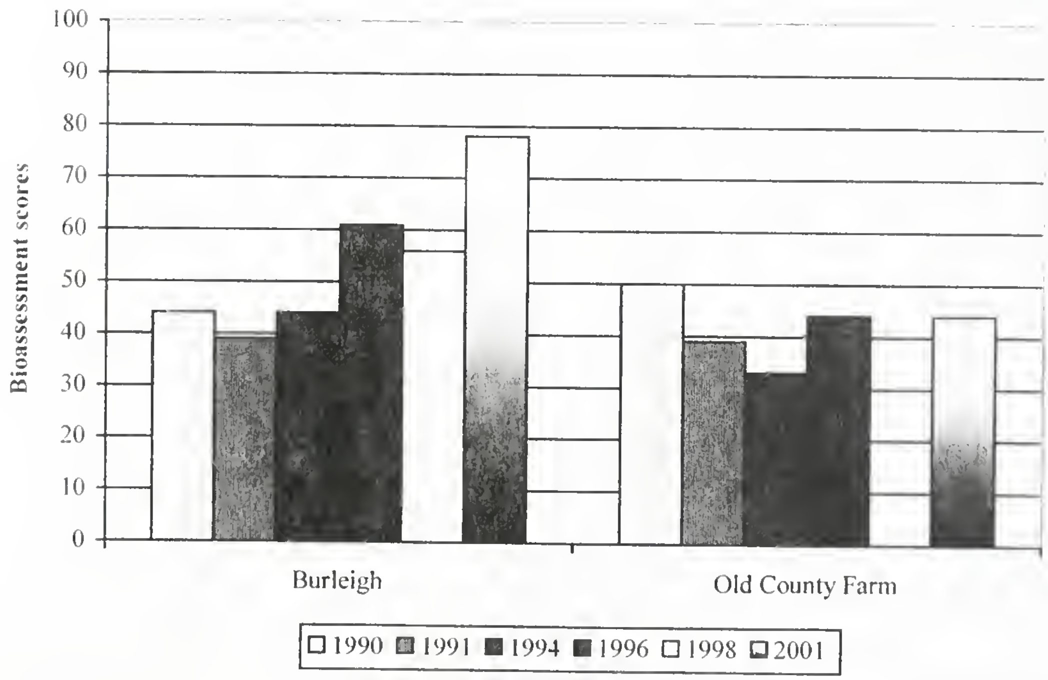


Table 5. Metric values and bioassessments for two sites on Big Spring Creek in six years of data collection. Metric values for 1991, 1994, and 1996 are mean values based upon two replicate samples, and metric scores were assigned based on the mean values. No data was collected at the Old County Farm site in 1998.

Big Spring Creek at Burleigh						
	1990	1991	1994	1996	1998	2001
Metrics						
Ephemeroptera richness	4	4	4.5	5	2	6
Plecoptera richness	1	1	1	1.5	1	2
Trichoptera richness	4	3.5	6	5.5	3	5
Sensitive taxa richness	0	0	0	1	1	0
Percent tolerant taxa'	3	34	22.5	14	15	5
Percent filter-feeders	35	18	18.5	6	0	5
	Metric scores					
Ephemeroptera richness	2	2	2	2	1	3
Plecoptera richness	1	1	1	2	1	2
Trichoptera richness	2	2	3	3	2	3
Sensitive taxa richness	0	0	0	1	1	0
Percent tolerant taxa	3	1	1	1	1	3
Percent filter-feeders	0	1	1	2	3	3
Total score	8	7	8	11	9	14
Percent of maximum	**44**	**39**	**44**	**61**	**50**	**78**
Use support*	**PART**	**PART**	**PART**	**PART**	**PART**	**FULL**
Impairment class	**MOD**	**MOD**	**MOD**	**SLI**	**MOD**	**SLI**
Big Spring Creek at Old County Farm						
	1990	1991	1994	1996		2001
Metrics						
Ephemeroptera richness	5	3.5	3.5	3.5		2
Plecoptera richness	1	2.5	0.5	1		1
Trichoptera richness	3	3.5	5	4.5		4
Sensitive taxa richness	0	0	0	0		0
Percent tolerant taxa	31	37.5	63	22		8
Percent filter-feeders	5	14.5	11	21.5		7
	Metric scores					
Ephemeroptera richness	2	2	2	2		1
Plecoptera richness	1	2	0	1		1
Trichoptera richness	2	2	3	3		2
Sensitive taxa richness	0	0	0	0		0
Percent tolerant taxa	1	0	0	1		2
Percent filter-feeders	3	1	1	1		2
Total score	9	7	6	8		8
Percent of maximum	**50**	**39**	**33**	**44**		**44**
Use support*	**PART**	**PART**	**PART**	**PART**		**PART**
Impairment class	**MOD**	**MOD**	**MOD**	**MOD**		**MOD**

[1] Classifications: (NON) non-impaired, (SLI) slightly impaired, (MOD) moderately impaired, (SEVERE) severely impaired. See Table 3b.

*Use support designations: See Table 3a.

Figure 1. Stream and riparian habitat assessment: two sites on Big Spring Creek, May 2001.

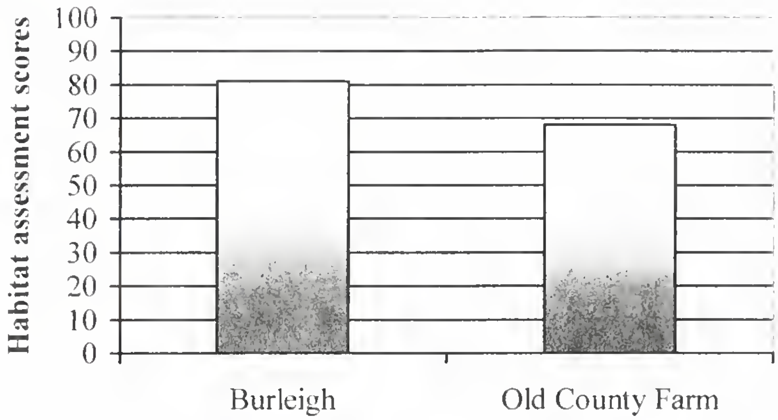


Table 4. Stream and riparian habitat assessment: two sites on Big Spring Creek. May 2001.

Maximum possible score	Parameter	Burleigh	Old County Farm
10	Riffle development	8	7
10	Benthic substrate	8	6
20	Embeddedness	16	15
20	Channel alteration	16	8
20	Sediment deposition	14	10
20	Channel flow status	20	20
20	Bank stability r / l	10 / 9	10 / 6
20	Bank vegetation r / l	9 / 9	10 / 6
20	Vegetated zone r / l	5 / 5	8 / 2
160	Total	129	108
	Percent of maximum	**81**	**68**
	CONDITION*	**OPT**	**SUB**

*Condition categories: Optimal (OPT) > 80% of maximum score; Sub-optimal (SUB) 75 - 56%; Marginal (MARG) 49 - 29%; Poor <23%. Adapted from Plafkin et al. 1988.

Bioassessment scores calculated for the benthic invertebrate assemblage at Burleigh in 1998 indicated partial support of designated uses and moderate impairment of biotic health. Ephemeroptera and Plecoptera taxa richnesses were much lower than expected, and the relative abundance of generally tolerant taxa was higher than expected. By 2001, however, conditions have apparently improved; bioassessment scores in that year indicate full support of designated uses, and only slight impairment of biotic health. The overall score was diminished only by the lack of any sensitive taxa at the site in 2001. Ephemeroptera taxa richness increased by 4 taxa since 1998; both Plecoptera taxa richness and Trichoptera taxa richness increased as well. In addition, the abundance of tolerant taxa improved to within expected limits in 2001.

Since 1994, the site at Burleigh consistently obtained a higher bioassessment score than the downstream site at the Old County Farm. In 2001, the overall score indicated partial support of designated uses and moderate impairment of biotic health at the lower site. Both Ephemeroptera and Plecoptera taxa richnesses were much lower than expected, and the relative proportions of both tolerant taxa and filter-feeding taxa were somewhat higher than expected.

Aquatic invertebrate communities

Biotic index values calculated from the composition of the invertebrate community at Burleigh were low in both 1998 and 2001; the value decreased somewhat between the two years (2.49 in 1998, 2.14 in 2000). In addition, mayfly taxa richness increased from 2 taxa in 1998 to 6 taxa in 2001. These findings suggest that water quality was essentially unimpaired by nutrient pollution or thermal challenges in both years. It is possible that improvement in mayfly richness and biotic index scores is attributable to different seasons of sampling; 1998 sampling took place in August, while 2001 sampling took place in May. Other differences in taxonomic composition of samples between the two years may also be due to seasonal differences.

Caddis fly taxa richness was marginal in 1998, but improved by 2001; still, the number of "clinger" taxa between the two years remained stable. Eight such "clinger" taxa were collected at Burleigh in 1998, and 9 were collected in 2001. This suggests that benthic substrates were clean and unimpaired by fine sediment deposition. Abundant diverse instream habitats are suggested by the ample numbers of predator taxa present in the two years (4 in 1998, 6 in 2001). In both years, samples were dominated by the caddis fly Lepidostoma sp., which comprised 40% of the sampled assemblage in 1998, and 28% in 2001. The abundance of this shredder suggests that riparian inputs of large organic debris is plentiful and that hydrologic conditions favor retention of this material. Functional components of the benthic invertebrate community seem to be well-balanced, with adequate representation of grazers, scrapers, predators, and shredders.

Few stonefly taxa were present in either year, which suggests that reach-scale habitat may be altered unfavorably, either by channelization, extensive streambank instability, riparian zone inadequacies, or other impact. The single stonefly taken in 1998, however, was a single individual of the sensitive perlodid *Cultus* sp.

Below Lewistown, the biotic index value in 2001 was also low, suggesting good water quality and cold temperatures, but the mayfly taxa richness was much lower than expected; only 2 taxa were collected. Low mayfly taxa richness is associated with

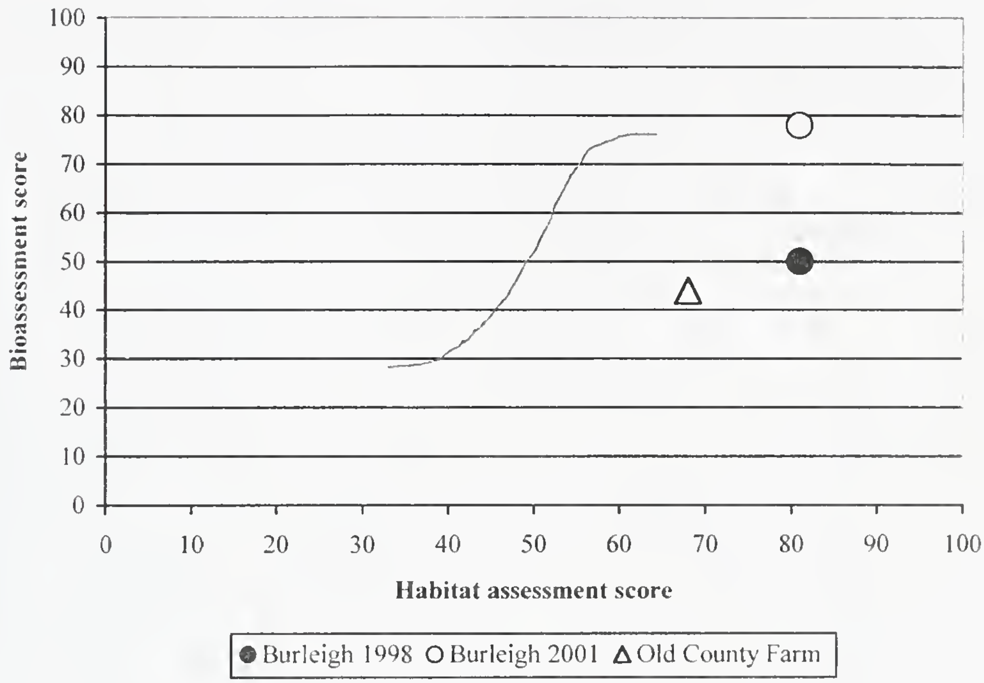
degraded water quality, and is probably the more sensitive indicator. In the same sampling period, the site above Lewistown supported 6 mayfly taxa There was a slight increase in the number of filter-feeders in this reach compared to the Burleigh site, due to a moderate increase in numbers of the caddis fly *Hydropsyche* sp. While the numbers collected were sufficient to affect the scoring of the related bioassessment metric, the numbers do not necessarily imply an increase in suspended organic material Only one predator taxon, the perlodid stonefly *Isoperla* sp., was collected at the Old County Farm site, suggesting that instream habitats may have been diminished in quantity or quality in this reach, perhaps by deposited sediments. Seven "clinger" taxa were present in the sample, suggesting that some clean substrate surfaces were available, but interstitial habitats may have been impacted by fines. The single stonefly taxon suggests that reach-scale habitat disturbances may have impaired the benthic community.

As at Burleigh, the assemblage collected at the Old County Farm site was dominated by the shredder *Lepidostoma* sp., which comprised 43% of the animals in the sample. Scrapers and grazers were also adequately represented among the functional groups, but, as mentioned previously, there was a dearth of predatory taxa.

CONCLUSIONS

- Water quality appeared to be unimpaired by nutrients or warm temperatures at Burleigh, above Lewistown. At the Old County Farm site, below Lewistown, there was some evidence of water quality impairment; mayfly taxa richness was quite low.
- Above Lewistown, slight impairment of biotic health may be due to mild reach-scale disturbances, such as loss of riparian zone function or channel alteration.
- Some degree of habitat disturbance may impair biotic health at the Old County Farm site; deposition of fine sediments may have diminished instream habitat complexity.
- The relationship between habitat assessment scores and bioassessment scores suggests that water quality was a limiting factor to the biotic health of the benthic communities at the Old County Farm site, but that both good habitat and unimpaired water quality supported a healthy assemblage at the Burleigh site. Habitat degradation was also present at the Old County Farm site, primarily in the form of sediment deposition, resulting in a relatively low habitat assessment score. Figure 3 illustrates this. The point representing the Old County Farm site lies below a line describing the expected relationship between habitat and biotic health when water quality is unimpaired. This suggests that bioassessment scores are somewhat lower than would be expected if impairment was due to habitat degradation alone, and suggests that water quality impairment, perhaps by warm water temperatures or nutrient pollution, was an additional factor limiting biotic health at this site.

Figure 3. Total bioassessment scores plotted against habitat assessment scores for two sites on Big Spring Creek, August 1998 and May 2001, assuming that habitat conditions remained unchanged at Burleigh between the two years.The red line describes the hypothetical relationship expected when water quality is good and biotic health is determined predominantly by habitat quality (Barbour and Stribling 1991).



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APPENDIX

Taxonomic data and summaries

Two sites on Big Spring Creek, Fergus County:
Burleigh, August 1998 and May 2001
Old County Farm site, May 2001

Aquatic Invertebrate Taxonomic Data

Site Name: Big Spring Creek at Burleigh

Site ID: 8/13/98 Approx. percent of sample used: 100

Taxon	Quantity	Percent	HBI	FFG
Diphetor hageni	1	0.66	5	CG
Ephemerella inermis	7	4.61	1	CG
Total Ephemeroptera	**8**	**5.26**		
Cultus sp.	1	0.66	2	PR
Total Plecoptera	**1**	**0.66**		
Micrasema sp.	1	0.66	1	MH
Glossosoma sp.	26	17.11	1	SC
Lepidostoma sp.-sand case larvae	60	39.47	1	SH
Total Trichoptera	**87**	**57.24**		
Elmidae	3	1.97	4	CG
Heterlimnius sp.	4	2.63	4	CG
Optioservus sp.	23	15.13	4	SC
Total Coleoptera	**30**	**19.74**		
Atherix sp	1	0.66	4	PR
Empididae - pupa	4	2.63	6	PR
Hexatoma sp.	1	0.66	2	PR
Total Diptera	**6**	**3.95**		
Cladotanytarsus sp.	5	3.29	7	CG
Eukiefferiella sp.- early instar	4	2.63	8	OM
Micropsectra sp.	6	3.95	7	CG
Pagastia sp.	2	1.32	1	CG
Parametriocnemus sp.	2	1.32	5	CG
Polypedilum sp.	1	0.66	6	OM
Total Chironomidae	**20**	**13.16**		
Grand Total	152	100.00		

Aquatic Invertebrate Summary Data

Site Name: Big Spring Creek at Burleigh **Site ID: 8/13/98**

TOTAL ABUNDANCE	152
Ephemeroptera + Plecoptera + Trichoptera (EPT) abundance	96
TOTAL NUMBER OF TAXA	18
Number EPT taxa	6

TAXONOMIC GROUP COMPOSITION

GROUP	#TAXA	ABUNDAN	PERCENT
Misc. Taxa	0	0	0.00
Odonata	0	0	0.00
Ephemeroptera	2	8	5.26
Plecoptera	1	1	0.66
Hemiptera	0	0	0.00
Megaloptera	0	0	0.00
Trichoptera	3	87	57.24
Lepidoptera	0	0	0.00
Coleoptera	3	30	19.74
Diptera	3	6	3.95
Chironomidae	6	20	13.16

RATIOS OF TAX GROUP ABUNDANCES

EPT/Chironomidae	4.80

FUNCTIONAL FEEDING GROUP (FFG) COMPOSITION

GROUP	#TAXA	ABUNDAN	PERCENT
Predator	4	7	4.61
Parasite	0	0	0.00
Collector-gatherer	8	30	19.74
Collector-filterer	0	0	0.00
Macrophyte-herbivore	1	1	0.66
Piercer-herbivore	0	0	0.00
Scraper	2	49	32.24
Shredder	1	60	39.47
Xylophage	0	0	0.00
Omnivore	2	5	3.29
Unknown	0	0	0.00

RATIOS OF FFG ABUNDANCES

Scraper/Collector-filterer	#DIV/0!
Scraper/(Scraper + C.filterer)	1.00
Shredder/Total organisms	0.26

CONTRIBUTION OF DOMINANT TAXA

TAXON	ABUNDANCE	PERCENT
Lepidostoma sp.-sand case larv.	60	39.47
Glossosoma sp.	26	17.11
Optioservus sp.	23	15.13
Ephemerella inermis	7	4.61
Micropsectra sp.	6	3.95
SUBTOTAL 5 DOMINANTS	122	80.26
Cladotanytarsus sp.	5	3.29
Heterlimnius sp.	4	2.63
Empididae - pupa	4	2.63
Eukiefferiella sp.	4	2.63
TOTAL DOMINANTS	139	91.45

SAPROBIC INDICES

Hilsenhoff Biotic Index	2.49

DIVERSITY MEASURES

Shannon H (loge)	2.01
Shannon H (log2)	2.90
Evenness	0.70
Simpson D	0.21

COMMUNITY VOLTINISM ANALYSIS

TYPE	ABUNDANCE	PERCENT
Multivoltine	16	10.36
Univoltine	106	69.90
Semivoltine	30	19.74

	#TAXA	ABUNDANCE	PERCENT
Tolerant	1	23	15.13
Intolerant	1	1	0.66
Clinger	8	66	43.42

Aquatic Invertebrate Taxonomic Data

Site Name: Big Spring Creek

Site ID: Burleigh 5/25/01

Approx. percent of sample used: 7

Taxon	Quantity	Percent	HBI	FFG
Eiseniella tetraedra	3	0.91	8	CG
Fossaria sp.	1	0.30	6	CG
Physidae	2	0.61	8	CG
Acari	2	0.61	5	PA
Total Misc. Taxa	**8**	**2.43**		
Acentrello turbida	6	1.82	4	CG
Baetis tricaudatus	1	0.30	6	CG
Diphetor hageni	4	1.22	5	CG
Ephemerella inermis	62	18.84	1	CG
Rhithrogena sp	3	0.91	0	SC
Paraleptophlebia temporalis	3	0.91	4	CG
Total Ephemeroptera	**79**	**24.01**		
Hesperoperla pacifica	1	0.30	2	PR
Isoperla sp.	3	0.91	2	PR
Total Plecoptera	**4**	**1.22**		
Brachycentrus americanus	54	16.41	1	OM
Glossosoma sp.	2	0.61	1	SC
Hydropsyche sp	5	1.52	4	CF
Lepidostoma sp.-sand case larvae	93	28.27	1	SH
Rhyacophila Brunnea Gr	5	1.52	1	PR
Total Trichoptera	**159**	**48.33**		
Optioservus sp.	11	3.34	4	SC
Total Coleoptera	**11**	**3.34**		
Atherix sp.	2	0.61	4	PR
Chelifera sp	1	0.30	6	PR
Antocha sp	7	2.13	3	CG
Total Diptera	**10**	**3.04**		
Cladotanytarsus sp.	5	1.52	7	CG
Eukiefferiella Devonica Gr.	3	0.91	4	OM
Eukiefferiella Gracei Gr.	12	3.65	4	OM
Micropsectra sp	1	0.30	7	CG
Orthocladius sp.	11	3.34	6	CG
Pagastia sp	12	3.65	1	CG
Rheotanytarsus sp.	12	3.65	6	CF
Thienemannimyia Gr.	2	0.61	6	PR
Total Chironomidae	**58**	**17.63**		
Grand Total	**329**	**100.00**		

Aquatic Invertebrate Summary Data

Site Name: Big Spring Creek **Site ID: Burleigh 5/25/01**

TOTAL ABUNDANCE	356
Ephemeroptera + Plecoptera + Trichoptera (EPT) abundance	279
TOTAL NUMBER OF TAXA	18
Number EPT taxa	7

TAXONOMIC GROUP COMPOSITION

GROUP	#TAXA	ABUNDAN	PERCENT
Misc. Taxa	5	18	5.06
Odonata	0	0	0.00
Ephemeroptera	2	82	23.03
Plecoptera	1	9	2.53
Hemiptera	0	0	0.00
Megaloptera	0	0	0.00
Trichoptera	4	188	52.81
Lepidoptera	0	0	0.00
Coleoptera	1	20	5.62
Diptera	1	1	0.28
Chironomidae	4	38	10.67

RATIOS OF TAX GROUP ABUNDANCES

EPT/Chironomidae	7.34

FUNCTIONAL FEEDING GROUP (FFG) COMPOSITION

GROUP	#TAXA	ABUNDAN	PERCENT
Predator	1	9	2.53
Parasite	2	3	0.84
Collector-gatherer	6	113	31.74
Collector-filterer	2	26	7.30
Macrophyte-herbivore	0	0	0.00
Piercer-herbivore	0	0	0.00
Scraper	2	26	7.30
Shredder	1	153	42.98
Xylophage	0	0	0.00
Omnivore	4	26	7.30
Unknown	0	0	0.00

RATIOS OF FFG ABUNDANCES

Scraper/Collector-filterer	1.00
Scraper/(Scraper + C.filterer)	0.50
Shredder/Total organisms	0.12

CONTRIBUTION OF DOMINANT TAXA

TAXON	ABUNDANCE	PERCENT
Lepidostoma sp.-sand case larv	153	42.98
Ephemerella inermis	79	22.19
Hydropsyche sp.	25	7.02
Optioservus sp.	20	5.62
Eukiefferiella Devonica Gr.	18	5.06
SUBTOTAL 5 DOMINANTS	295	82.87
Orthocladius sp.	16	4.49
Polycelis coronata	13	3.65
Isoperla sp.	9	2.53
Helicopsyche borealis	6	1.69
Baetis tricaudatus	3	0.84
TOTAL DOMINANTS	342	96.07

SAPROBIC INDICES

Hilsenhoff Biotic Index	2.17

DIVERSITY MEASURES

Shannon H (loge)	1.50
Shannon H (log2)	2.17
Evenness	0.52
Simpson D	0.21

COMMUNITY VOLTINISM ANALYSIS

TYPE	ABUNDANCE	PERCENT
Multivoltine	53	14.89
Univoltine	279	78.23
Semivoltine	25	6.88

	#TAXA	ABUNDANCE	PERCENT
Tolerant	4	30	8.43
Intolerant	0	0	0.00
Clinger	7	138	38.76

Aquatic Invertebrate Taxonomic Data

Site Name: Big Spring Creek, County Farm
Site ID: 5/25/01

Approx. percent of sample used: 8

Taxon	Quantity	Percent	HBI	FFG
Polycelis coronata	13	3.65	4	CG
Nematoda	1	0.28	5	PA
Sphaeriidae	1	0.28	8	CG
Fossaria sp.	1	0.28	6	CG
Acari	2	0.56	5	PA
Total Misc. Taxa	**18**	**5.06**		
Baetis tricaudatus	3	0.84	6	CG
Ephemerella inermis	79	22.19	1	CG
Total Ephemeroptera	**82**	**23.03**		
Isoperla sp.	9	2.53	2	PR
Total Plecoptera	**9**	**2.53**		
Brachycentrus americanus	4	1.12	1	OM
Helicopsyche borealis	6	1.69	7	SC
Hydropsyche sp.	25	7.02	4	CF
Lepidostoma sp.-sand case larvae	153	42.98	1	SH
Total Trichoptera	**188**	**52.81**		
Optioservus sp.	20	5.62	4	SC
Total Coleoptera	**20**	**5.62**		
Tipula sp.	1	0.28	4	OM
Total Diptera	**1**	**0.28**		
Eukiefferiella Devonica Gr	18	5.06	4	OM
Orthocladius sp.	16	4.49	6	CG
Polypedilum sp	3	0.84	6	OM
Rheotanytarsus sp	1	0.28	6	CF
Total Chironomidae	**38**	**10.67**		
Grand Total	**356**	**100.00**		

Aquatic Invertebrate Summary Data

Site Name: Big Spring Creek, County Farm **Site ID: 5/25/01**

TOTAL ABUNDANCE	356
Ephemeroptera + Plecoptera + Trichoptera (EPT) abundance	279
TOTAL NUMBER OF TAXA	18
Number EPT taxa	7

TAXONOMIC GROUP COMPOSITION

GROUP	#TAXA	ABUNDAN	PERCENT
Misc. Taxa	5	18	5.06
Odonata	0	0	0.00
Ephemeroptera	2	82	23.03
Plecoptera	1	9	2.53
Hemiptera	0	0	0.00
Megaloptera	0	0	0.00
Trichoptera	4	188	52.81
Lepidoptera	0	0	0.00
Coleoptera	1	20	5.62
Diptera	1	1	0.28
Chironomidae	4	38	10.67

RATIOS OF TAX GROUP ABUNDANCES

EPT/Chironomidae	7.34

FUNCTIONAL FEEDING GROUP (FFG) COMPOSITION

GROUP	#TAXA	ABUNDAN	PERCENT
Predator	1	9	2.53
Parasite	2	3	0.84
Collector-gatherer	6	113	31.74
Collector-filterer	2	26	7.30
Macrophyte-herbivore	0	0	0.00
Piercer-herbivore	0	0	0.00
Scraper	2	26	7.30
Shredder	1	153	42.98
Xylophage	0	0	0.00
Omnivore	4	26	7.30
Unknown	0	0	0.00

RATIOS OF FFG ABUNDANCES

Scraper/Collector-filterer	1.00
Scraper/(Scraper + C.filterer)	0.50
Shredder/Total organisms	0.12

CONTRIBUTION OF DOMINANT TAXA

TAXON	ABUNDANCE	PERCENT
Lepidostoma sp.-sand case larv.	153	42.98
Ephemerella inermis	79	22.19
Hydropsyche sp.	25	7.02
Optioservus sp.	20	5.62
Eukiefferiella Devonica Gr.	18	5.06
SUBTOTAL 5 DOMINANTS	295	82.87
Orthocladius sp.	16	4.49
Polycelis coronata	13	3.65
Isoperla sp.	9	2.53
Helicopsyche borealis	6	1.69
TOTAL DOMINANTS	339	95.23

SAPROBIC INDICES

Hilsenhoff Biotic Index	2.17

DIVERSITY MEASURES

Shannon H (loge)	1.50
Shannon H (log2)	2.17
Evenness	0.52
Simpson D	0.21

COMMUNITY VOLTINISM ANALYSIS

TYPE	ABUNDANCE	PERCENT
Multivoltine	53	14.89
Univoltine	279	78.23
Semivoltine	25	6.88

	#TAXA	ABUNDANCE	PERCENT
Tolerant	4	30	8.43
Intolerant	0	0	0.00
Clinger	7	138	38.76